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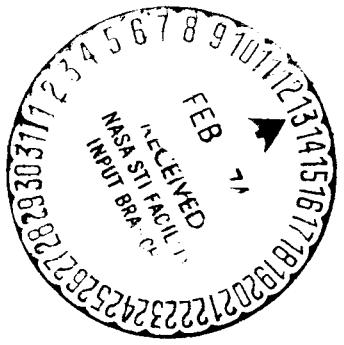
E-MISSION (AS-504/CSM-104/LM-4) NAVIGATION ERROR ANALYSIS



Mathematical Physics Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

MSC INTERNAL NOTE NO. 68-FM-241

PROJECT APOLLO

E-MISSION (AS-504/CSM-104/LM-4) NAVIGATION ERROR ANALYSIS

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Navigation Analysis Section
TRW Systems Group

September 16, 1968

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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SYMBOLS

ACN	Ascension Island
ANG	Antigua Island
BDA	Bermuda Island
CDH	constant differential height
CNB	Canberra, Australia
CRO	Carnarvon, Australia
CSI	coelliptic sequence initiation
CSM	command and service module
CYI	Grand Canary Island
DOI	descent orbit insertion
DPS	descent propulsion system
GBM	Grand Bahama Island
GDS	Goldstone, California
g.e.t	ground elapsed time
GWM	Guam
GYM	Guaymas, Mexico
HAW	Kauai, Hawaii
LM	lunar module
LOI	lunar orbit insertion
MAD	Madrid, Spain
MCC	midcourse maneuver
MIL	Merritt Island
MSFN	Manned Space Flight Network
NCC	corrective combination for maneuver N
NSR	slow rate for maneuver N

SPS	service propulsion system
S-IVB	Saturn IV
TEI	transearth injection
TEX	Corpus Christi, Texas
TLI	translunar injection
TPI	terminal phase initiation
USB	unified S-band

E-MISSION (AS-504/CSM-104/LM-4) NAVIGATION ERROR ANALYSIS

By

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1. SUMMARY

An error analysis of simulated observations by MSFN stations and the onboard tracking system has been performed to determine the accuracy of the ground and onboard differential correction schemes at specific times during the E-Mission. Relative uncertainties in the CSM/LM position and velocity vectors are presented during the LM-active and the CSM-active rendezvous phases.

The maximum MSFN navigation errors occur at TLI 2 (≅ 15 nautical miles, 111 feet per second). The chief contributor to the magnitude of the uncertainty at TLI 1 and TLI 2 is the S-IVB vent uncertainty. During the LM-active rendezvous sequence, MSFN monitors the CSM/LM relative state within an uncertainty three sigma RSS less than 0.3 nautical mile and 8 feet per second at the corrective combination for maneuver N (NCC) (Reference 1).

The results for the CSM-active rendezvous portion of the mission were taken from Reference 2. In this reference, a study was made to determine the respective effectiveness of the sextant and the crew optical alignment sight device. The analysis concluded that the sextant was superior for navigation. The maximum uncertainty (three sigma), when using the sextant during the CSM-active rendezvous, occurs at nominal time of NSR (≅1.6 nautical miles, 10 feet per second).

At initiation of the various descent propulsion system (DPS) and service propulsion system (SPS) burns during remaining mission phases, the uncertainties in the position and velocity vectors are less than 0.5 nautical mile and 3 feet per second, respectively. The three-sigma uncertainty in flight-path angle, speed, and velocity at nominal time of reentry are 7×10^{-6} radian, 0.024 foot per second and 500 feet, respectively.

2. INTRODUCTION

The purpose of this analysis is to compute an estimate of the accuracy with which the E-Mission trajectories can be computed from MSFN and onboard tracking data. This information is used to support a complete dispersion analysis for the E-Mission which computes an estimate of the fuel required to satisfy the mission objectives as well as expected trajectory dispersions. The analysis simulates the data incorporation and filtering techniques which may be employed either onboard or on the ground.

The navigation analysis results reported in this document are a combined effort of MSC and TRW. MSC provided the analysis for the CSM-active rendezvous using both onboard and MSFN data. The Orbit Error Analysis Program (OEAP) was used in the MSC analysis. MSC/TRW Task A-194 conducted the analysis of the LM-active rendezvous phase (Reference 3). The estimation accuracies presented for this phase reflect MSFN tracking only. The onboard navigation analysis for the LM-active rendezvous will be published as a TRW IOC by MSC/TRW Task A-194. Task A-153 conducted the navigation analysis for the remaining phases of the mission.

The computer programs used by MSC and TRW are identical in theory except that the OEAP uses analytic formulations while the TRW TAPP IV program uses an integrated trajectory for computation of the vehicle's ephemeris, tracking normal matrices, and propagation matrices.

The computer programs used by TRW for the analysis are described below (References 4, 5, 6, 7):

a) TAPP IV generates an integrated trajectory which matches a reference trajectory described in References 8 and 9. TAPP IV performs a complete tracking simulation for the mission including the generation of vehicle rise-set times and tracking information matrices when given input tracking stations, their associated data types and rates, and the trajectory. This program, also, generates coordinate transformation and state transition matrices.

b) FASTAP I and II process the TAPP IV tape for the two vehicles and form a tape containing all information, state transition, and coordinate transformation matrices for the mission.

c) MOFIT uses the information from the FASTAP II tape to compute the accuracies using a linear error analysis technique.

For the analysis, it was assumed that the ground and CSM onboard orbit determination schemes solved for three components of position and three components of velocity.

2.1 Error Model

The error sources considered in the generation of the ground tracking information matrices are the noise and bias on each data type and the uncertainties in drag, the earth's gravitational constant, S-IVB venting, and in the station locations for each station.

For the onboard estimation procedures (CSM-active rendezvous), platform misalignment and drift, sextant data biases and noise are considered in addition to the uncertainties implicit in the ground updates. Tables I and II list the one-sigma systematic errors and noise. These values are consistent with Reference 10.

Maneuver execution errors of 0.2 and 2 feet per second in each component of the velocity vector were also considered for the nominally non-zero maneuvers during the CSM-active and LM-active rendezvous phases, respectively.

2.2 Navigation Plan

The navigation plan consists of an observation schedule for both the earth-based and onboard tracking systems and specifications of how the resultant data are used. An error analysis, based on the navigation plan, provides an assessment of the effect of tracking and orbit prediction errors on the accuracy of the orbit determination.

The following guidelines were used in the development of the tracking plan (Reference 11):

a) Two or more stations cannot simultaneously track the same vehicle. When the vehicle is visible to more than one station, the station with the longest view period is to be used.

b) The C-band stations measure range, azimuth, and elevation angles at a rate of one set of observations per 9 seconds. The low speed sampling rate (1 set/6 seconds) was decreased to 1 set/9 seconds to allow for 33 1/3 percent data deletion due to skin tracking.

c) The noise associated with skin tracking data is a factor of 3 greater than the noise on C-band beacon tracking data.

d) For the LM- and CSM-active rendezvous phases, the ground update occurs at least 10 minutes prior to the separation burn. At least 10 minutes before an update, all tracking must have been completed for that update. The corresponding time allowance for the other mission phases are 30 and 10 minutes, respectively.

e) The S-band stations measure two-way doppler and x, y angles at a rate of one set of observables per 6 seconds. However, when a station's view period was greater than 10 minutes, the sampling rate was decreased to one set of observations per minute.

f) During the LM-active rendezvous, either vehicle may be tracked by a C-band and a S-band station simultaneously.

g) Tracking must occur above the 5 degrees elevation angle.

The MSFN and onboard tracking which was employed in this analysis is discussed below in four phases.

Phase I: Insertion to SPS trim maneuver

Phase II: LM-active rendezvous

Phase III: CSM-active rendezvous

Phase IV: TEI to reentry

The navigation error analysis is based on information contained in Reference 9, except for the LM-active rendezvous which is based on Reference 8. Figure 1 is an event schedule which presents the order of the updates and maneuvers.

Phase I

The lift-off time for the trajectory simulation is 1900 hours GMT, December 1, 1968. The launch phase is completed at S-IVB cutoff 11:35. 28 (min:sec), g. e. t., at which time the S-IVB/CSM/LM is inserted into a 100-nautical miles circular parking orbit. The first TLI opportunity occurs upon S-IVB reignition at 3:16:22 (hr:min:sec), g. e. t. The E-Mission timeline provides for two TLI opportunities, with the second one occurring approximately one revolution after the first. CRO will send the update for both opportunities at 2:28 (hr:min), g. e. t. and 4:28 (hr:min), g. e. t., respectively.

At apogee of the second high ellipse (7:31:34 (hr:min:sec), g. e. t.), the SPS is ignited for a MCC maneuver. The update for this maneuver is sent from CRO at 7:0 (hr:min), g. e. t. The simulated LOI burn occurs at 14:32:21 (hr:min:sec), g. e. t. ACN transmits the update at 14:0 (hr:min), g. e. t. The circularization burn (1:06:11:55 (day:hr:min:sec), g. e. t.), places the spacecraft (SC) in a 150-nautical miles circular orbit. The update for the maneuver is sent from CRO at 1:05:35 (day:hr:min), g. e. t.

Also included in this phase is a simulation of two LM DPS burns for the LLM and a SPS trim burn. A MSFN update is sent from CNB at 1:21:52 (day:hr:min), g. e. t., for the DOI burn which occurs at 1:21:41:31 (day:hr:min:sec), g. e. t. Approximately 73 minutes after the DOI burn, a second DPS maneuver is initiated. The update is sent from CRO at 1:23:18 (day:hr:min), g. e. t. The SPS trim burn which is performed prior to LM active rendezvous is updated by the Redstone tracking ship at 2:3:48 (day:hr:min), g. e. t. The burn occurs approximately 52 minutes later. Figures 2 through 7 are bar graphs of the tracking schedule employed for the analysis during Phase I.

Phase II

The navigation analysis results for this phase are based on MSFN tracking only. The tracking simulation employed in this phase reflects the accuracy with which the ground can monitor the rendezvous sequence and not the accuracy with which the ground can compute the rendezvous if used as a backup navigation system.

To further elaborate, the analysis simulates a MSFN update prior to the separation maneuver, after which time no ground updates were simulated. However, both C- and S-band stations tracked after separation and their data were used to compute the trajectories of the CSM and LM (i. e., no time allowance was made for ground updates) at time of burn initiation.

Based on the profile employed by MSC/TRW Task A-194, the MSFN update for the separation maneuver (2:23:28 (day:hr:min), g. e. t.), is sent from CRO at 2:23:20 (day:hr:min), g. e. t. Figures 8 and 9 present the MSFN tracking coverage for the separation through rendezvous phase. The rise-set times are referenced to the time of launch based on the revised mission profile. The numbers 0, 1, and 2, printed by the visibility periods in Figures 8 and 9 indicate which vehicle configuration was tracked by which station. The number 0 printed by a station specifies that the station tracks the docked vehicle. Similarly, the numbers 1 and 2 designate tracking of the LM and CSM, respectively. If no number is printed by the visibility period of a station, the vehicle is visible to the station, but its data is not included in the differential correction. The LM was given priority in this selection since it is the active vehicle.

Phase III

The duration of this phase is approximately 10 hours. Three coasting orbits of S-band tracking precede the first two burns which separate the CSM from the LM. After nulling the 1 foot per second separation burn, a second separation maneuver is performed at approximately 4:01:17 (day:hr:min), g. e. t. The update for this maneuver is sent from CRO at 4:0:54 (day:hr:min), g. e. t. After separation the onboard tracking system becomes prime.

Between NSR and TPI, 22 marks of sextant data were taken. The 22 marks were initialized with a diagonal weighting(W) matrix of 1000 feet and 1 foot per second. The tracking normal matrix was then propagated through TPI and used as a priori information to be combined with the 8 marks of sextant data taken between TPI and MCC 1. Following MCC 1, 2 marks were taken. These new data were combined with the a priori information and used to compute the relative error in the CSM-LM trajectories at MCC 2 and TPF.

Phase IV

The fourth phase is a simulation of the transearth phase of the lunar landing mission. Three revolutions of tracking data were used to compute the update from BDA at 6:0:1 (day:hr:min), g. e. t., for the TEI maneuver. The update for the transearth MCC maneuver (7:22:13:23 (day:hr:min:sec), g. e. t) is sent from CRO at 7:21:30 (day:hr:min), g. e. t. The SPS deorbit maneuver occurs at 9:21:45 (day:hr:min), g. e. t. and the update for this SPS maneuver is transmitted from Redstone at 9:21:0 (day:hr:min), g. e. t. Entry occurs approximately 17 minutes later.

Figures 10, 11, and 12 present the MSFN tracking that was used in the analysis during Phase IV.

3. RESULTS

The three-sigma values of the uncertainties in the position and velocity as determined in this study are presented in Table III. The uncertainties for the burns are computed at the nominal time of ignition for each burn. The three-sigma values listed in Table I are associated with a Gaussian distribution with zero mean.

Table IV presents the covariance matrices representing the estimated accuracy associated with the SC position and velocity vectors at the time of burn initiation. Also included in Table IV are the covariance matrices which relate the accuracy with which the MSFN can monitor the LM-active rendezvous. These matrices do not represent the estimation errors associated with the rendezvous sequence since the update time constraints were not adhered to in this phase of the analysis. The matrices associated with the CSM active rendezvous phase included both ground and onboard data. The onboard system was considered prime after CSM-LM separation.

4. CONCLUSIONS

1. The large uncertainties in position and velocity at TLI 1 and TLI 2 are chiefly due to the uncertainity associated with the S-IVB venting.

2. The navigation analysis for the LM-active rendezvous phase presented is not sufficient for determining the accuracy with which the rendezvous can be computed when using either the primary or secondary navigation system. The analysis represents an estimate of how accurately the MSFN can monitor the rendezvous. MSC/TRW Task A-194 will publish an error analysis report, based on the onboard navigation system in the near future.

3. If there were no execution errors associated with the maneuvers during the CSM-active rendezvous, no intervehicular measurements would be required for good relative state knowledge at TPI and beyond (Reference 2).

4. Based on the analysis conducted in Reference 2, SXT measurements, with a W matrix of 1000 feet and 1 foot per second (W not reinitialized after TPI), should be used on the E-Mission CSM-active rendezvous.

5. The MSFN coverage for all non-rendezvous related maneuvers seems adequate for the entire E-Mission.

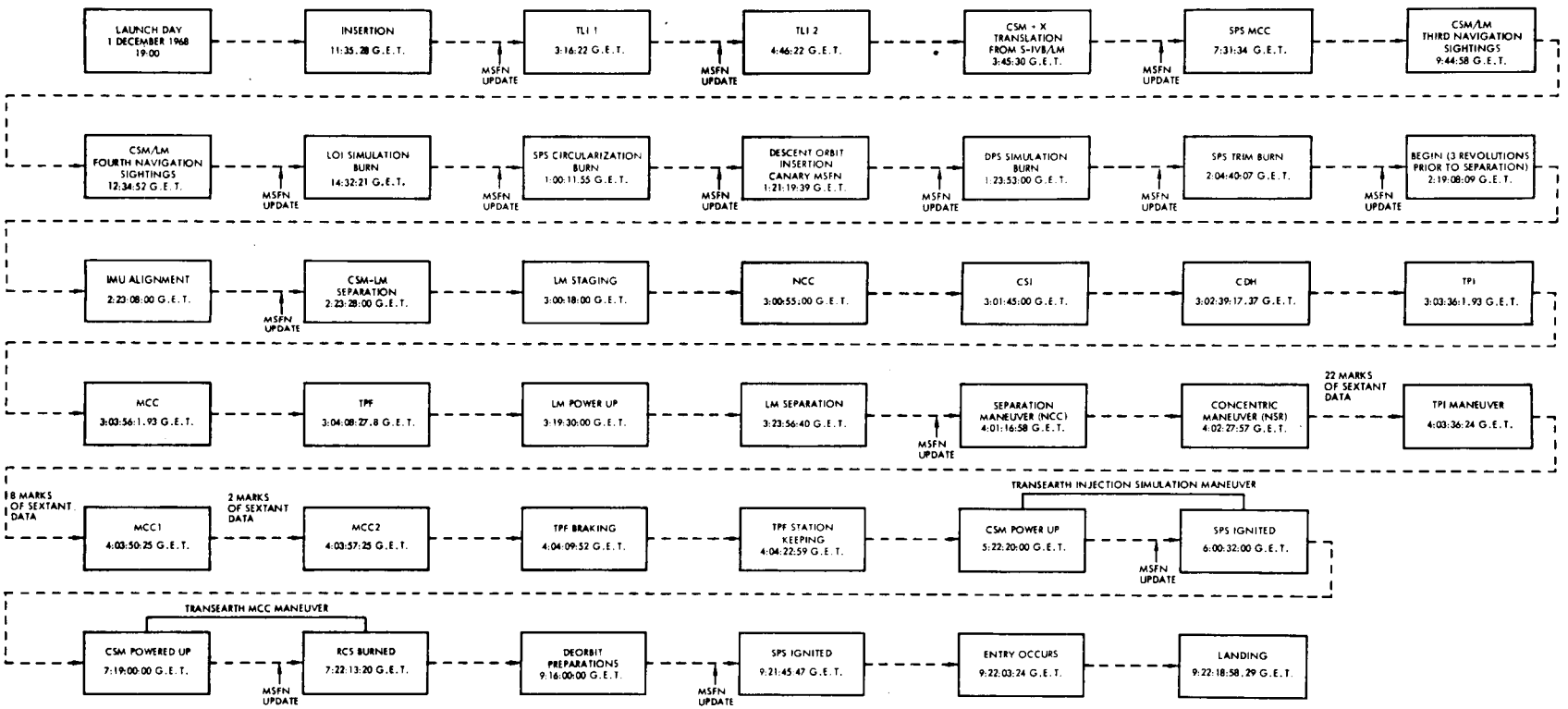

Figure 1. E-Mission Sequence of Events

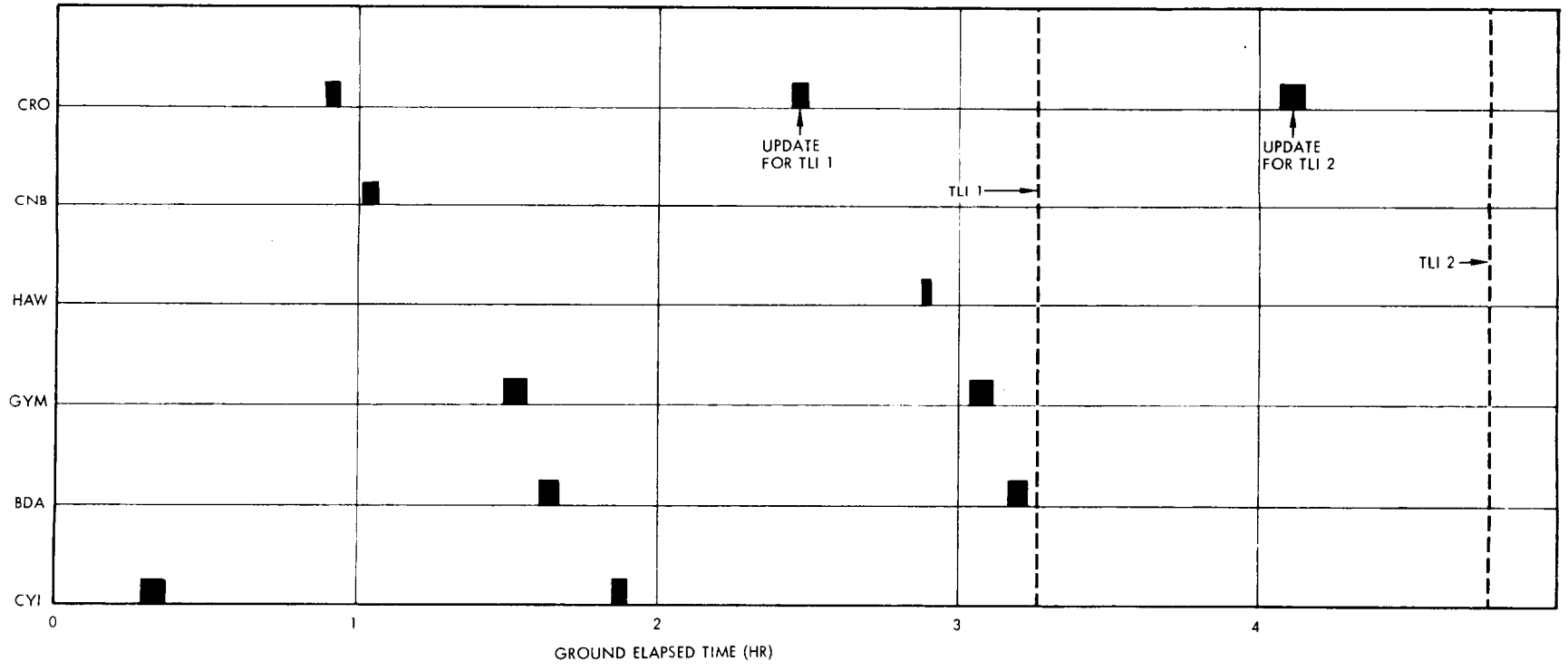

Figure 2. MSFN Tracking Prior to TLI 1 and 2

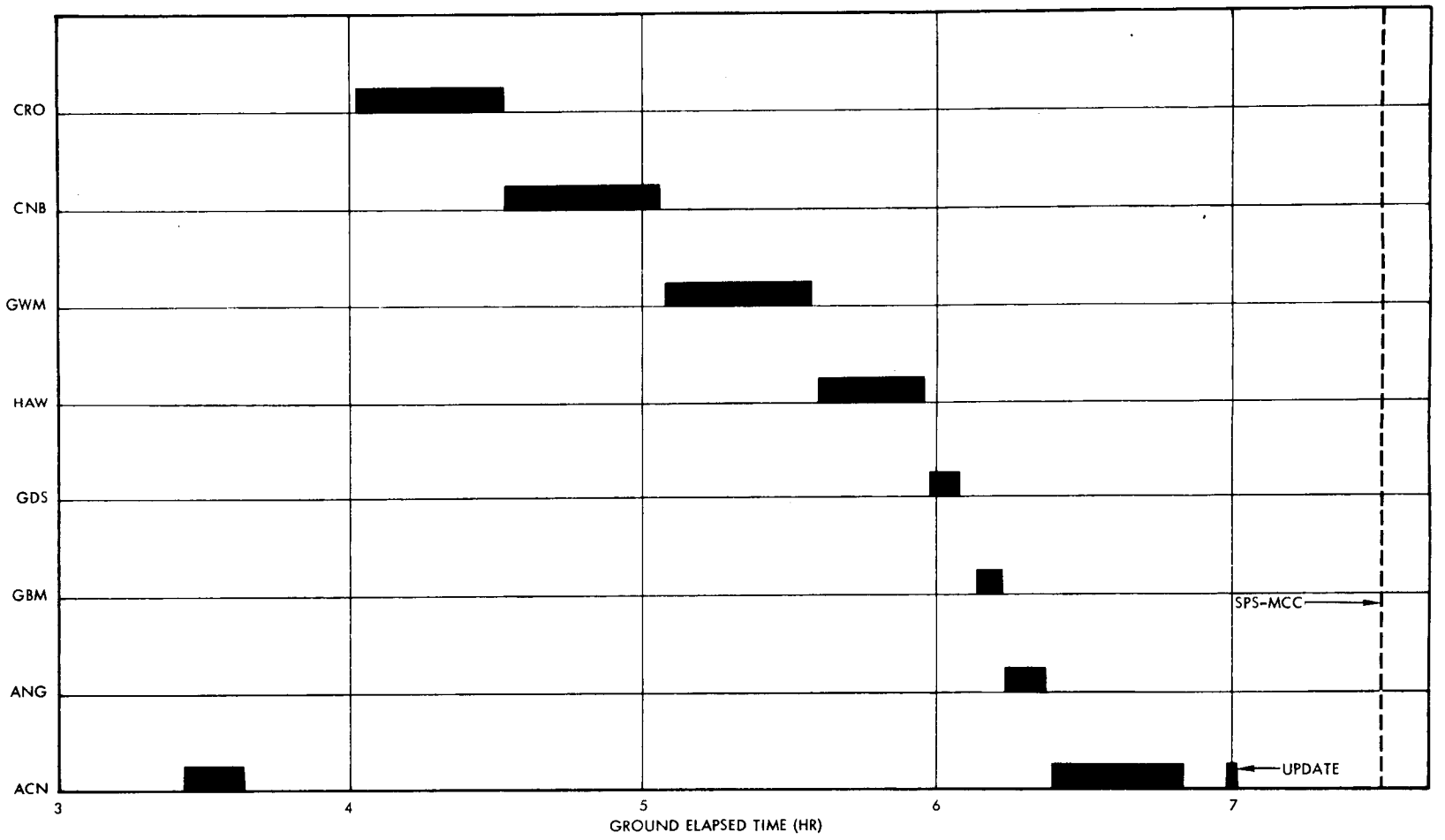

Figure 3. MSFN Tracking Prior to MCC

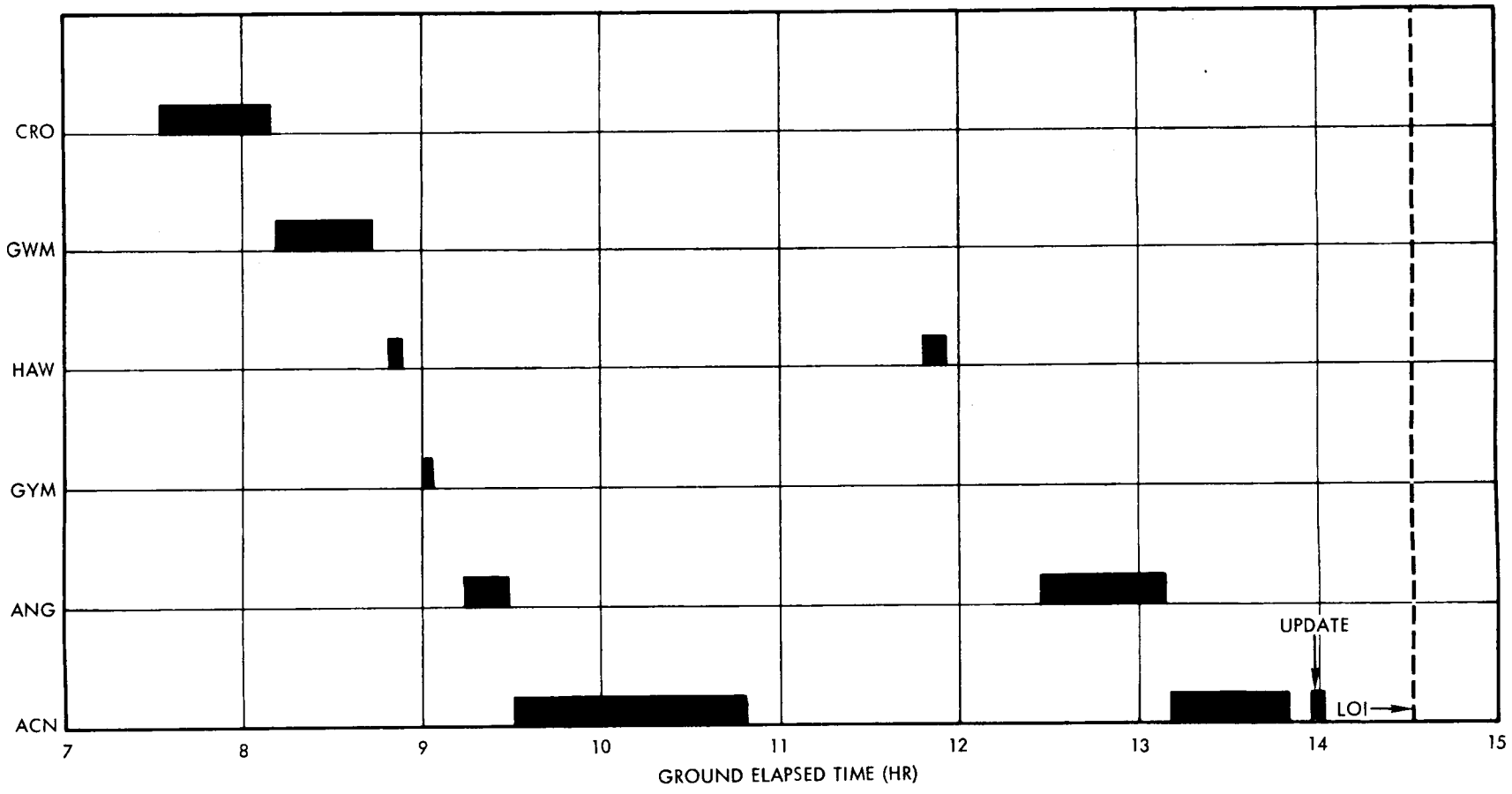

Figure 4. MSFN Tracking Prior to LOI

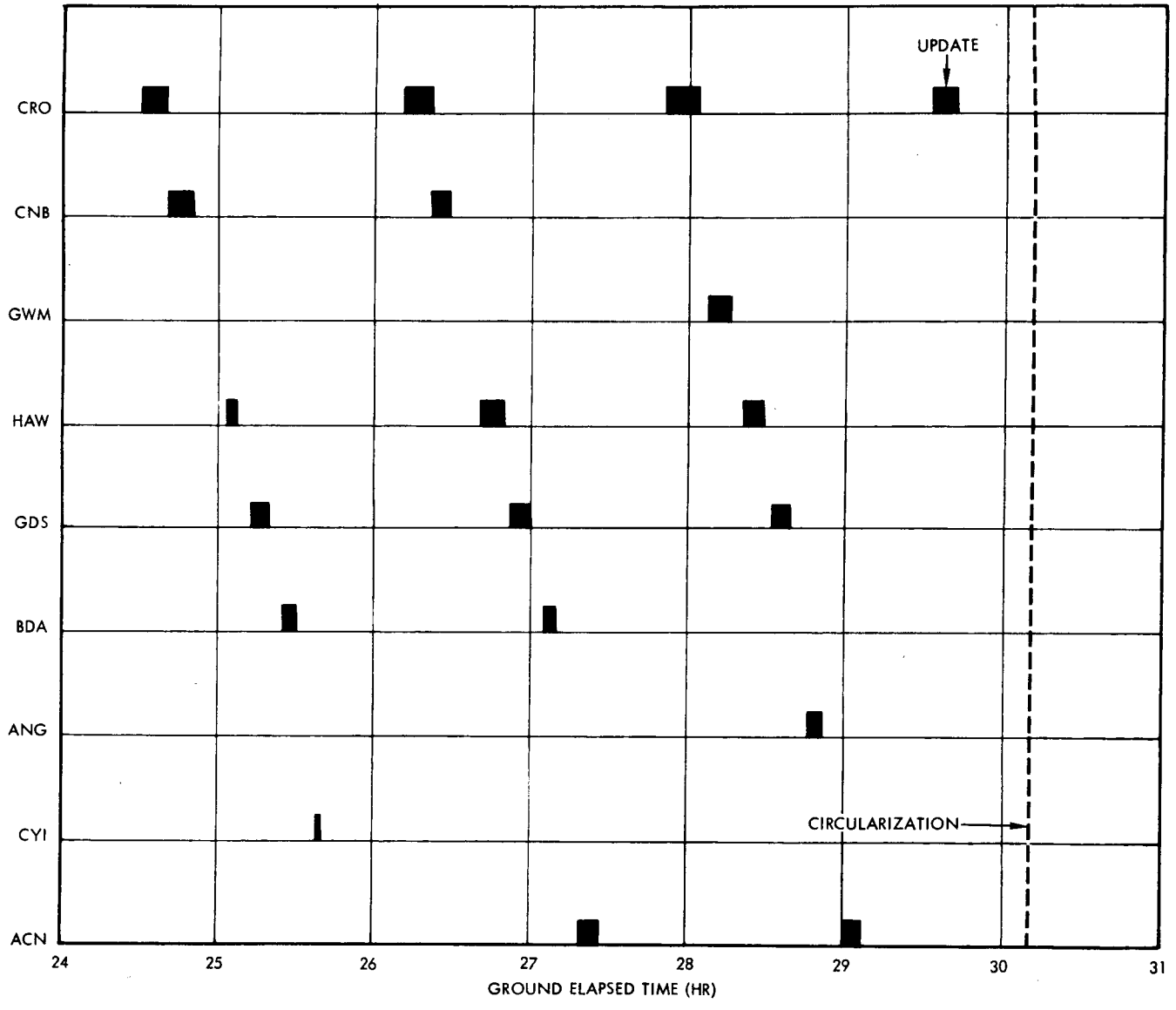

Figure 5. MSFN Tracking Prior to Circularization

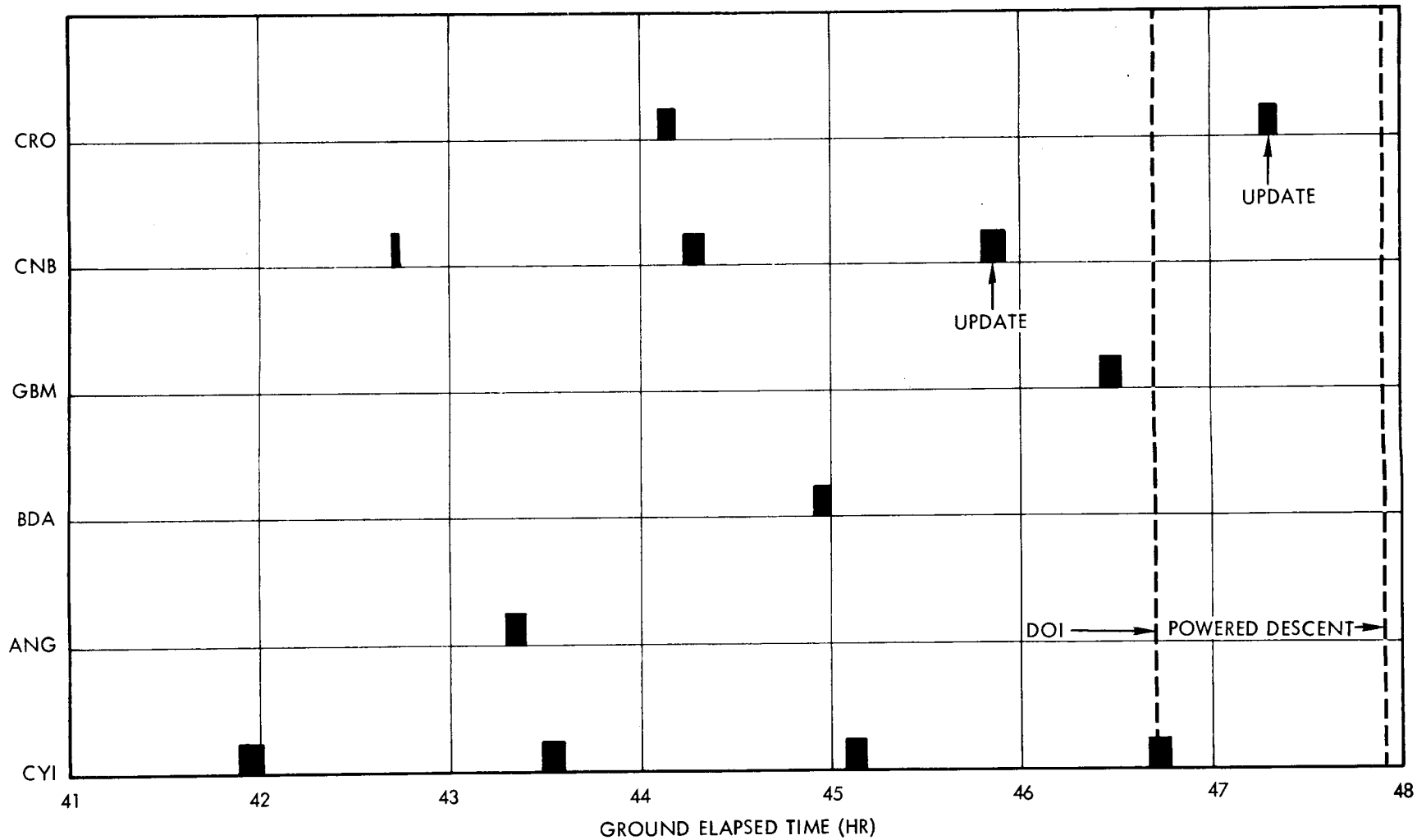

Figure 6. MSFN Tracking Prior to LM DPS Maneuvers

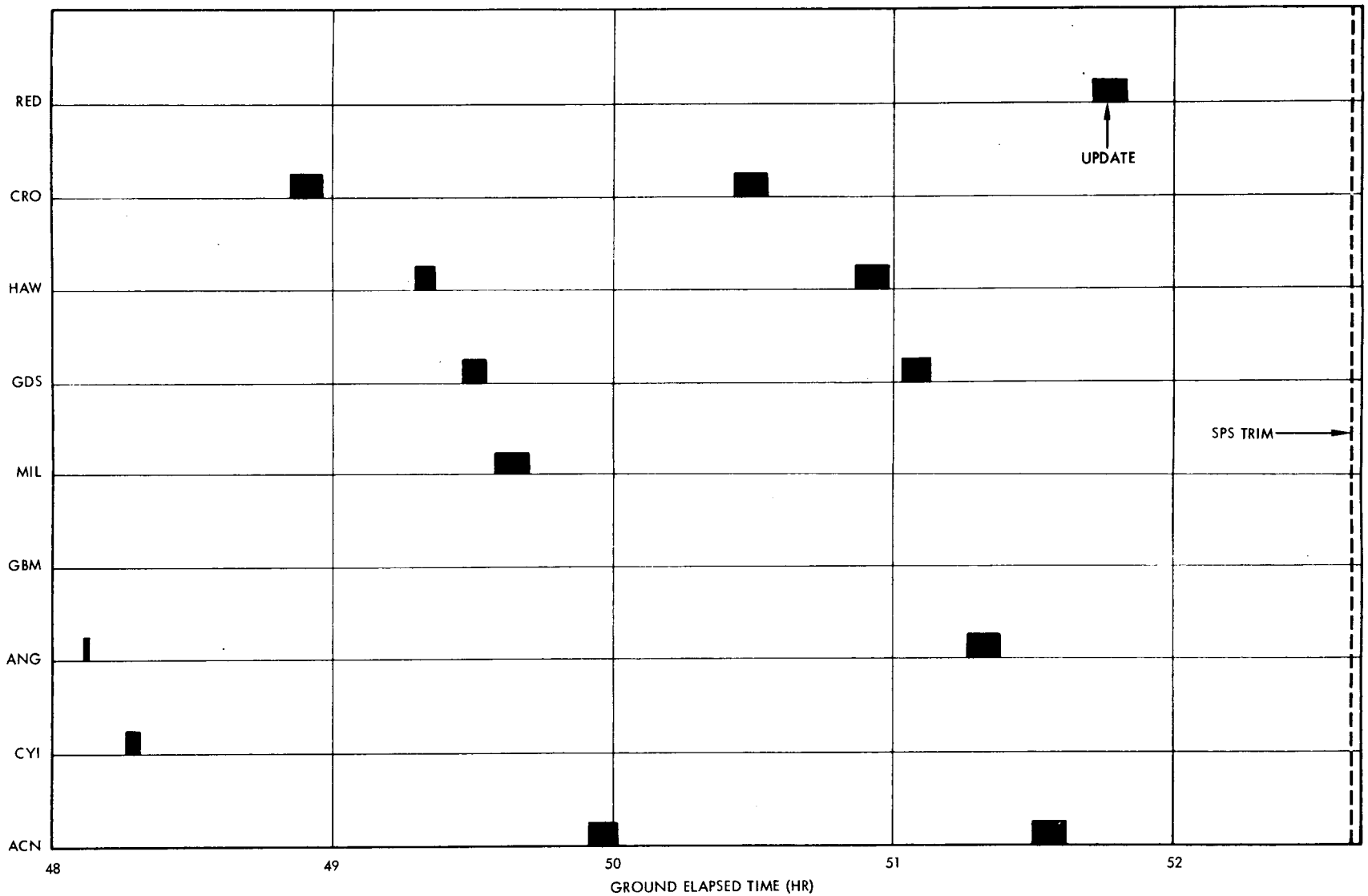

Figure 7. MSFN Tracking Prior to SPS Time

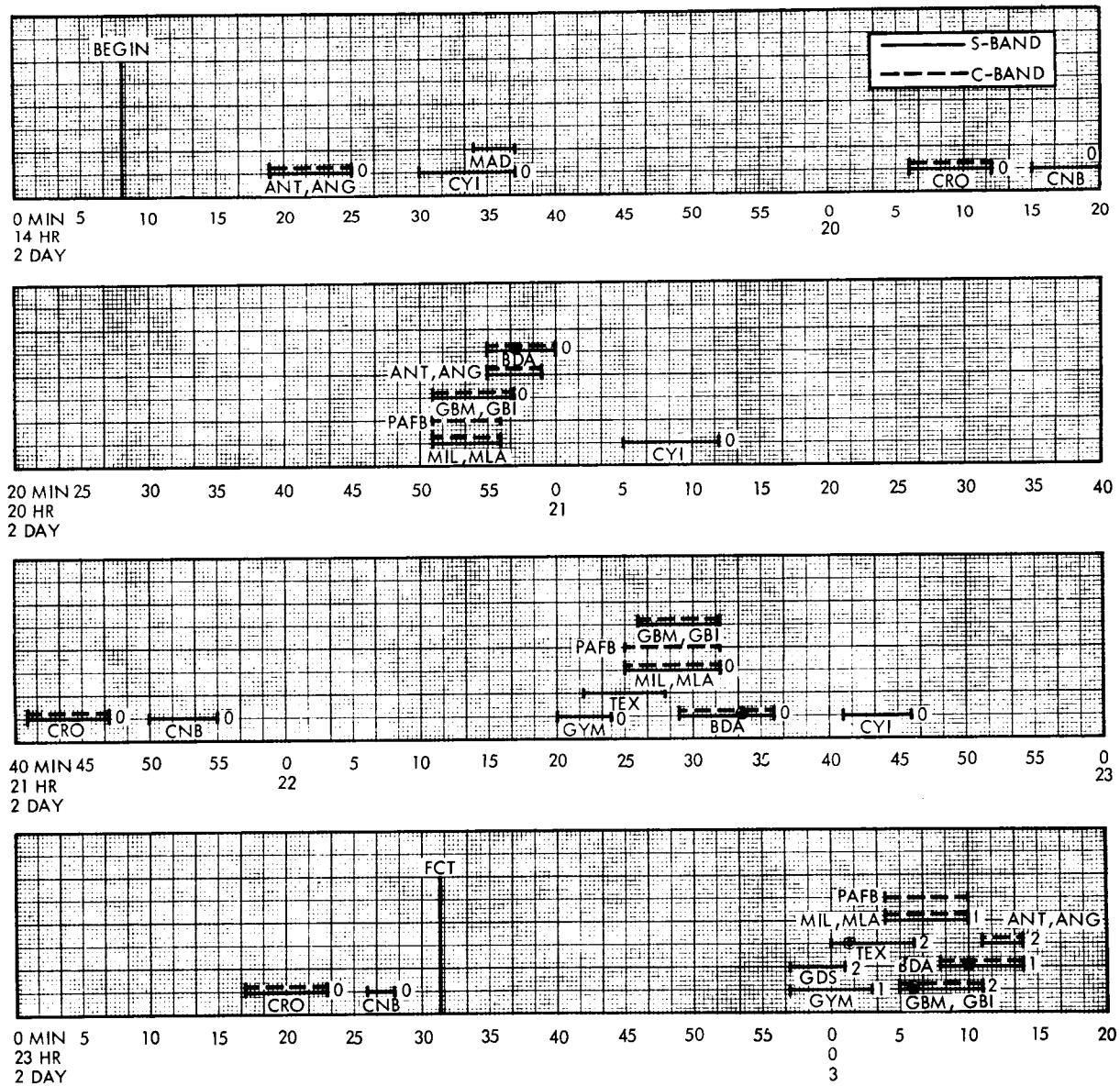

Figure 8. MSFN Tracking Prior to CSM/LM Separation

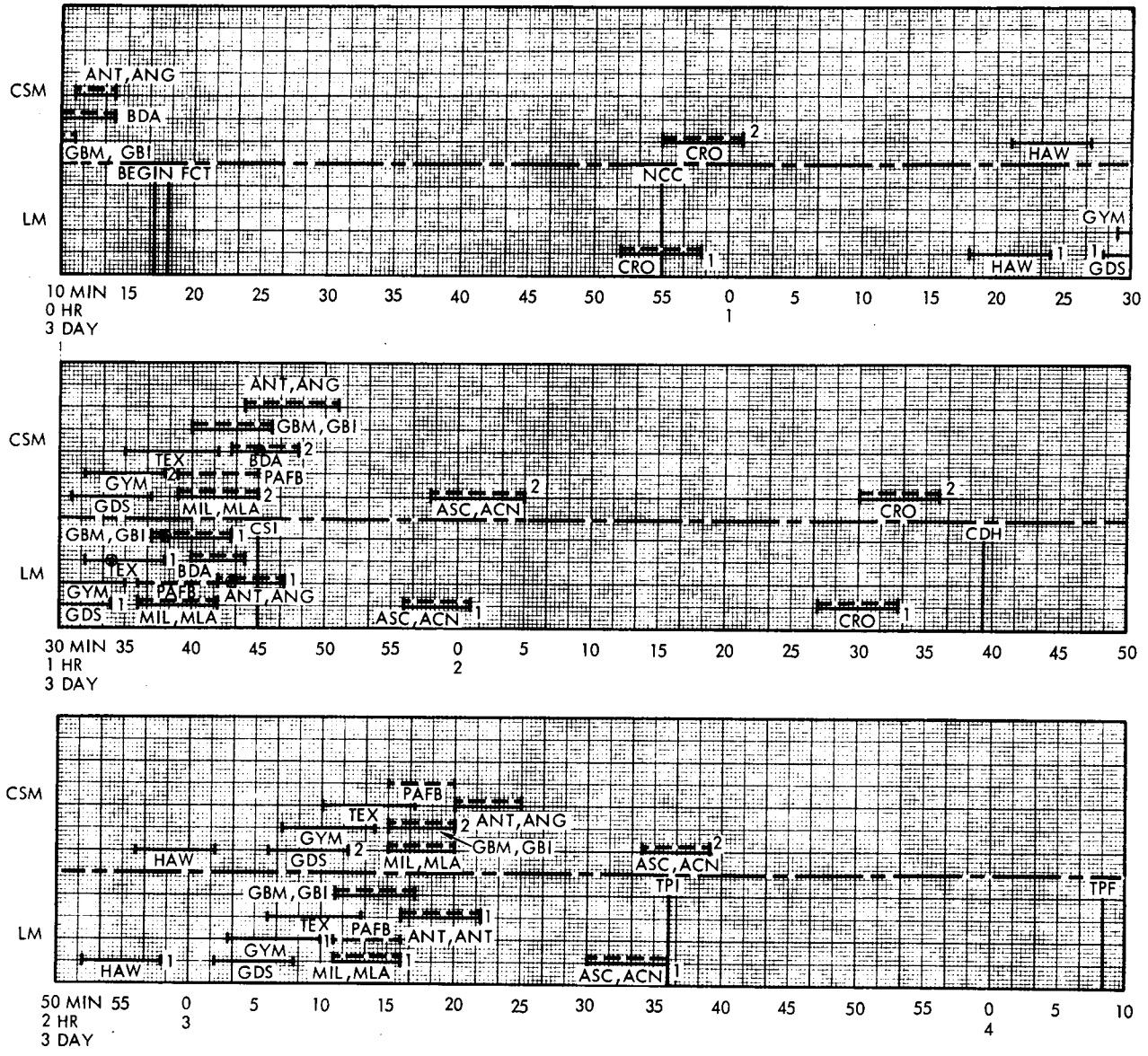

Figure 9. MSFN Tracking During LM-Active Rendezvous

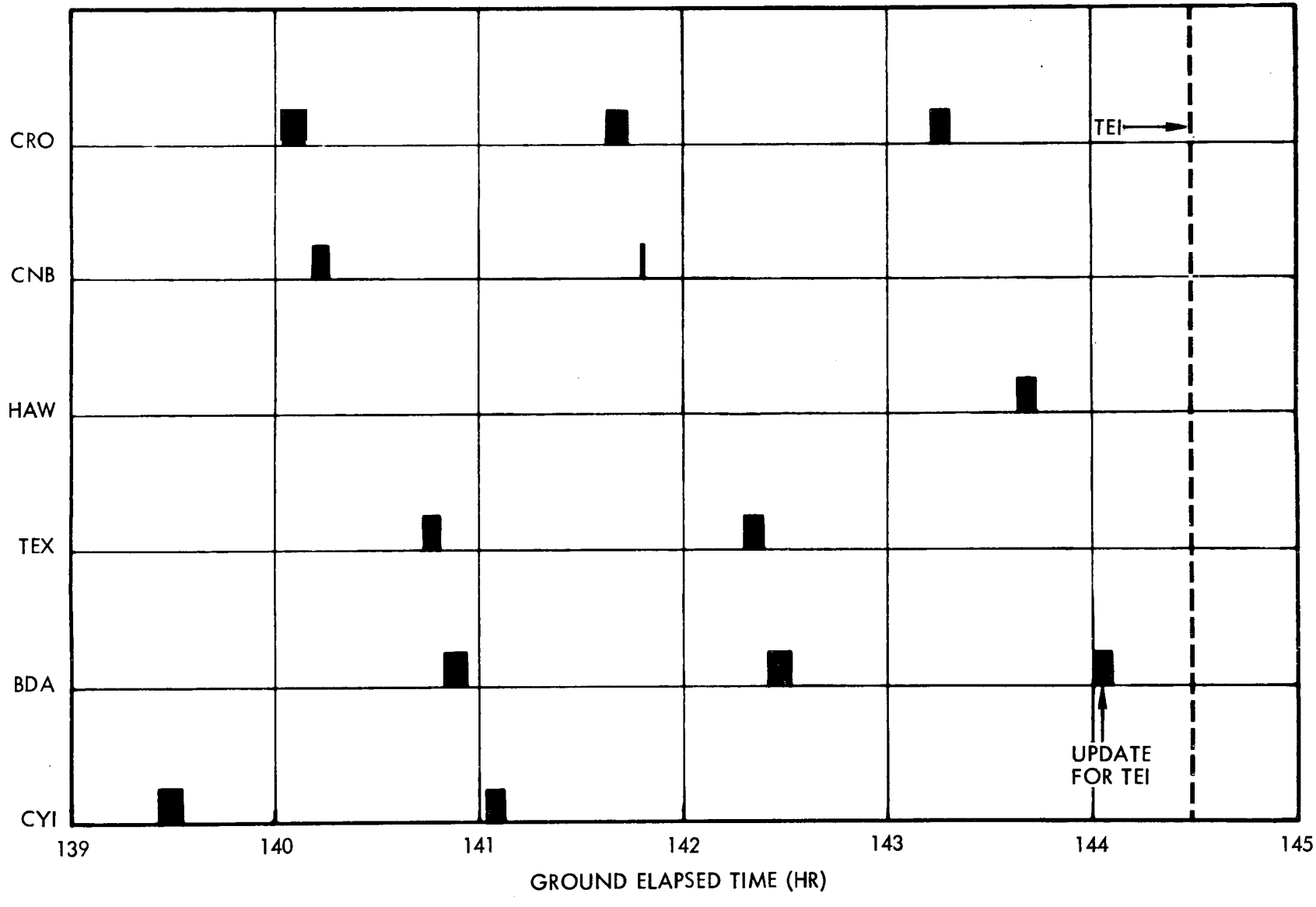

Figure 10. MSFN Tracking Prior to TEI

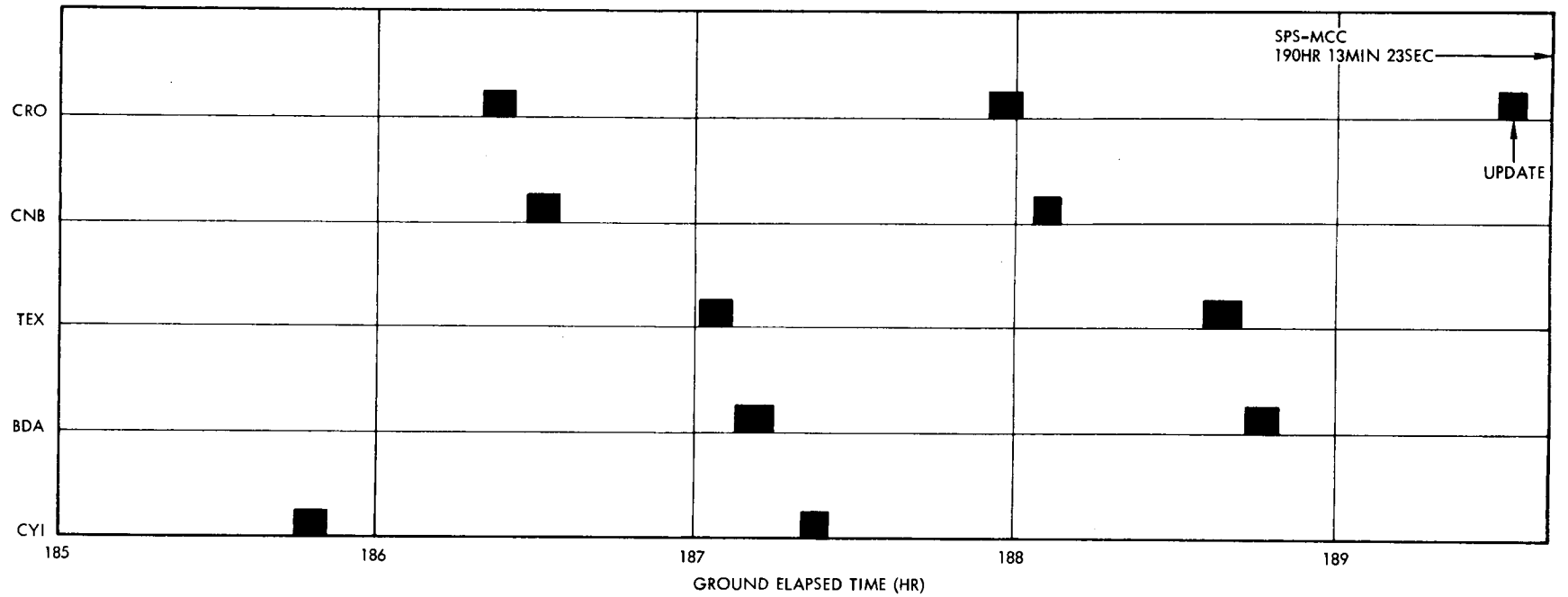

Figure 11. MSFN Tracking Prior to Transearth MCC

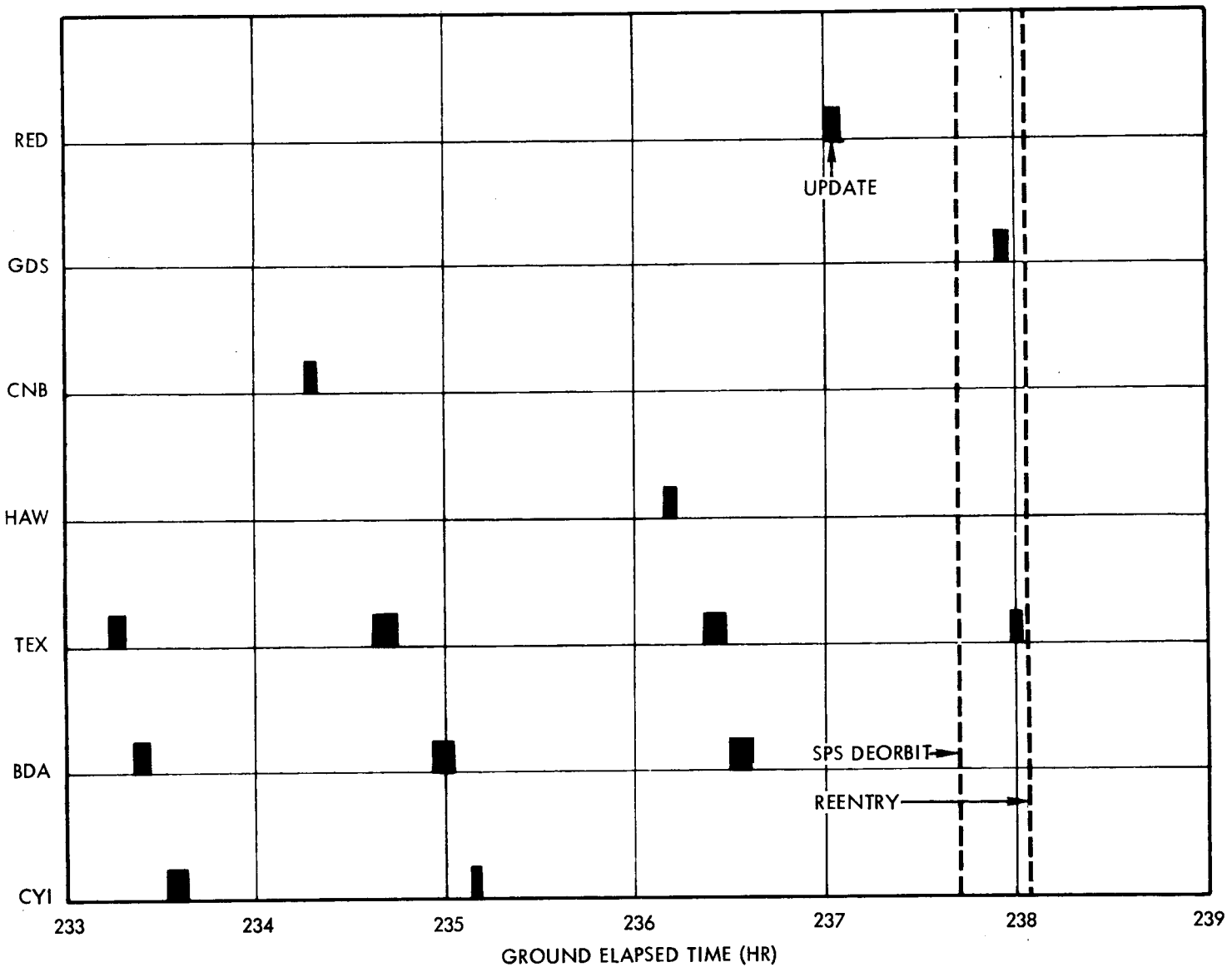

Figure 12. MSFN Tracking Prior to SPS Deorbit and Reentry

Table I. One-Sigma Values of MSFN Error Sources

USBS Tracking Accuracy

	Bias	Noise
X-Y Mount	1.6 mrad	0.8 mrad
Two-Way Doppler	0.03 fps	0.02 fps

C-Band Tracking Accuracy (Skin Track)

	Bias	Noise
Azimuth and Elevation	0.3 mrad	0.45 mrad
Range	40 ft	60 ft

Station Location Uncertainties

Station	Latitude (rad)	Longitude (rad)	Altitude (ft)
CRO	$0.92114602 \times 10^{-5}$	1.0665901×10^{-5}	190.3
CNB	$0.92114602 \times 10^{-5}$	1.0665901×10^{-5}	216.5
HAW	$0.67873917 \times 10^{-5}$	$0.77570191 \times 10^{-5}$	141.1
GDS	$0.53329506 \times 10^{-5}$	$0.58177643 \times 10^{-5}$	131.2
GYM	$0.48481369 \times 10^{-5}$	$0.58177643 \times 10^{-5}$	134.5
CWM	3.1028070×10^{-5}	3.19977×10^{-5}	105.0
TEX	$0.48481369 \times 10^{-5}$	$0.53329506 \times 10^{-5}$	131.2
MIL	$0.48481369 \times 10^{-5}$	$0.58177643 \times 10^{-5}$	131.2
GBM	$0.48481369 \times 10^{-5}$	$0.58177643 \times 10^{-5}$	134.5
BDA	$0.58177643 \times 10^{-5}$	$0.67813917 \times 10^{-5}$	141.1
ANG	$0.53329506 \times 10^{-5}$	$0.58177643 \times 10^{-5}$	137.8
CYI	2.2301430×10^{-5}	2.4725498×10^{-5}	105.0

Table I. One-Sigma Values of MSFN Error Sources (Continued)

	Station Location Uncertainties		
Station	Latitude (rad)	Longitude (rad)	Altitude (ft)
ACN	1.6483666×10^{-5}	1.6968479×10^{-5}	105.0
MAD	$0.48481369 \times 10^{-5}$	$0.38785094 \times 10^{-5}$	141.0

Drag factor uncertainty: 0.10 (represents 10 percent of nominal drag)

Uncertainty in earth gravitational constant: $.106 \times 10^{12}$ $(\text{int ft})^3/\text{sec}^2$

S-IVB vent uncertainty: 2 lb

Table II. One-Sigma Values of Onboard Error Sources

Source	1σ Value
Sextant shaft and trunnion bias	0.2 mrad per axis
Sextant shaft and trunnion noise	0.2 mrad per axis
Platform misalignment	0.2 mrad per axis
Platform drift rate	0.5 mrad per axis hour
Gravitational constant	0.106×10^{12} $(\text{int ft})^3/\text{sec}^2$

Table III. E-Mission Navigation Uncertainties

Event	3σ U(ft)	3σ V(ft)	3σ W(ft)	3σ $\dot{U}$(fps)	3σ $\dot{V}$(fps)	3σ $\dot{W}$(fps)	RSS (ft)	RSS (fps)
Insertion to SPS trim maneuver								
TLI 1	8,500	60,000	3,100	74.6	4.8	2.0	61,000	74.8
TLI 2	8,000	88,000	8,900	110.0	3.7	15.5	89,000	111.1
SPS-MCC	440	1,600	1,200	0.4	0.2	0.5	2,059	0.7
LOI	630	720	1,100	0.8	0.6	1.2	1,500	1.6
Circularization	230	330	340	0.4	0.3	0.6	530	0.7
DOI	250	890	1,800	0.7	0.3	1.2	2,000	1.4
Powered descent	320	620	720	0.7	0.4	1.5	1,000	1.7
SPS trim	250	460	410	0.5	0.3	0.7	660	1.0
LM-active rendezvous								
Separation	250	700	890	0.4	0.3	0.6	1,200	0.8
Relative LM-staging	1,800	1,900	2,600	3.4	1.7	2.2	3,700	4.4
Relative - NCC	990	320	1,300	2.6	0.3	6.6	1,700	7.1
Relative - CSI	460	440	1,000	0.8	0.4	1.1	1,200	1.4
Relative - CDH	180	510	1,200	0.5	0.2	0.4	1,400	0.7
Relative - TPI	490	1,200	920	1.3	0.4	0.8	1,600	1.6
CSM-active rendezvous								
Separation	1,000	4,000	1,000	4.7	1.4	1.4	4,300	5.1
Relative - NSR	1,200	9,600	500	10.1	1.0	0.6	9,700	10.2

Table III. E-Mission Navigation Uncertainties (Continued)

Event	3σ U(ft)	3σ V(ft)	3σ W(ft)	3σ U(fps)	3σ V(fps)	3σ W(fps)	RSS (ft)	RSS (fps)
Relative - TPI	1,700	5,300	1,000	6.5	1.3	1.3	5,600	6.8
Relative - MCC1	1,400	1,100	190	2.3	0.9	1.0	1,800	2.6
Relative - MCC2	1,000	260	82	1.7	0.5	0.5	1,100	1.8
Relative - TPF	1,200	1,000	340	2.2	1.0	0.3	1,600	2.4
TEI to reentry								
TEI	290	580	400	0.6	0.3	0.8	760	1.0
TEI - MCC	330	2,200	430	2.4	0.4	1.2	2,300	2.7
SPS - deorbit	290	1,400	980	1.2	0.3	0.7	1,700	1.4
Reentry	500	270	1,000	0.7	0.2	3.1	1,100	3.2

Table IV. Covariance Matrices (One Sigma)

Format for covariance matrices

σ_{uu}	σ_{uv}	σ_{uw}	$\sigma_{u\dot{u}}$	$\sigma_{u\dot{v}}$	$\sigma_{u\dot{w}}$
	σ_{vv}	σ_{vw}	$\sigma_{v\dot{u}}$	$\sigma_{v\dot{v}}$	$\sigma_{v\dot{w}}$
		σ_{ww}	$\sigma_{w\dot{u}}$	$\sigma_{w\dot{v}}$	$\sigma_{w\dot{w}}$
			$\sigma_{\dot{u}\dot{u}}$	$\sigma_{\dot{u}\dot{v}}$	$\sigma_{\dot{u}\dot{w}}$
symmetrical				$\sigma_{\dot{v}\dot{v}}$	$\sigma_{\dot{v}\dot{w}}$
					$\sigma_{\dot{w}\dot{w}}$

The coordinate system for the covariance matrices is described below:

u - in the direction of the geocentric radius vector of the vehicle at the time of the event

v - orthogonal to u, pointing downrange in the orbit plane

w - mutually orthogonal to u and v, completing the righthanded system

The units for position and velocity are feet and feet per second, respectively. The relative covariances are in the coordinates of the CSM.

S-IVB/CSM/LM Covariance at TLI 1

7.9834361+06	-5.6711704+07	2.8761193+06	7.0287620+04	-4.4835342+03	1.7551111+03
-5.6711704+07	4.0277243+08	-2.0334993+07	-4.9919739+05	3.1905819+04	-1.2355813+04
2.8761193+06	-2.0334993+07	1.0642352+06	2.5198381+04	-1.6318972+03	6.4352125+02
7.0287620+04	-4.9919739+05	2.5198381+04	6.1871490+02	-3.9542153+01	1.5308377+01
-4.4835342+03	3.1905819+04	-1.6318972+03	-3.9542153+01	2.5256456+00	-1.0029894+00
1.7551111+03	-1.2355813+04	6.4352125+02	1.5308377+01	-1.0029894+00	4.2273553-01

S-IVB/CSM/LM Covariance at TLI 2

7.0441186+06	-7.8197782+07	7.8876537+06	9.7140355+04	-3.2199758+03	1.3696733+04
-7.8197782+07	8.7100536+08	-8.7859355+07	-1.0820977+06	3.5597754+04	-1.5261118+05
7.8876537+06	-8.7859355+07	8.8847165+06	1.0915219+05	-3.5922278+03	1.5412887+04
9.7140355+04	-1.0820977+06	1.0915219+05	1.3443586+03	-4.4212740+01	1.8959955+02
-3.2199758+03	3.5597754+04	-3.5922278+03	-4.4212740+01	1.4957014+00	-6.2327571+00
1.3696733+04	-1.5261118+05	1.5412887+04	1.8959955+02	-6.2327571+00	2.6777313+01

CSM/LM Covariance at SPS-MCC

	1	2	3	4	5	6
1	2.1887322+04	-3.8121765+02	7.7385926+03	1.1360840+00	-3.7868452-01	5.8500244+00
2	-3.8121752+02	2.9481576+05	1.0142786+05	-7.6318312+01	2.8970620+00	-3.3700307+01
3	7.7385926+03	1.0142786+05	1.5438701+05	-2.7787906+01	-8.9525442-01	6.5610451+00
4	1.1360840+00	-7.6318312+01	-2.7787906+01	2.0050037-02	-1.2454636-03	9.1666307-03
5	-3.7868452-01	2.8970621+00	-8.9525440-01	-1.2454636-03	3.4160861-03	-2.7934879-03
6	5.8500244+00	-3.3700307+01	6.5610451+00	9.1666307-03	-2.7934879-03	2.9076154-02

CSM/LM Covariance at LOI

	1	2	3	4	5	6
1	4.4409041+04	8.9088866+03	5.7628444+04	-2.7872078+00	-3.5414988+01	2.1381878+01
2	8.9088865+03	5.8351968+04	-8.5511803+03	-5.7145640+01	-1.1877817+01	3.0514104+01
3	5.7628444+04	-8.5511803+03	1.4568185+05	2.4884441+01	-5.6216917+01	-3.7671938+01
4	-2.7872078+00	-5.7145640+01	2.4884441+01	6.8261199-02	6.5706830-03	-1.9246365-02
5	-3.5414987+01	-1.1877818+01	-5.6216917+01	6.5706830-03	4.3229888-02	-2.2596875-02
6	2.1381878+01	3.0514104+01	-3.7671938+01	-1.9246365-02	-2.2596875-02	1.6728777-01

CSM/LM Covariance at Circularization

	1	2	3	4	5	6
1	5.7358115+03	2.2558740+02	3.2965829+03	4.3715215-01	2.3012733-01	1.2901136+00
2	2.2558740+02	1.2082693+04	-3.0745523+03	-1.3418032+01	-3.5676980-01	6.1021724+00
3	3.2965829+03	-3.0745523+03	1.2958889+04	4.9826678+00	-1.0599888+00	2.6593226-01
4	4.3715215-01	-1.3418034+01	4.9826678+00	1.7290989-02	-3.9858999-04	-5.5291475-03
5	2.3012733-01	-3.5677004-01	-1.0599888+00	-3.9858999-04	8.1811405-03	-9.2814676-04
6	1.2901136+00	6.1021724+00	2.6593226-01	-5.5291475-03	-9.2814676-04	3.3981189-02

CSM/LM Covariance at DOI

7.1120185+03	-1.2873485+04	-2.4488252+04	6.3775431+00	-1.7796519+00	-2.2606190+01
-1.2873485+04	8.8139446+04	3.1544615+04	-6.0700469+01	1.5317309+01	8.9306731+01
-2.4488252+04	3.1544615+04	3.6284696+05	2.5048476+01	2.9668677+01	1.6558415+02
6.3775431+00	-6.0700469+01	2.5048476+01	5.1483557-02	-6.3964137-03	-4.1969531-02
-1.7796516+00	1.5317309+01	2.9668677+01	-6.3964138-03	1.0912097-02	2.3531980-02
-2.2606190+01	8.9306731+01	1.6558415+02	-4.1969531-02	2.3531980-02	1.6169161-01

CSM/LM Covariance at Powered Descent

1.1775737+04	5.9174166+03	1.3698578+04	-3.6210643+00	-7.4684279+00	-2.5763240+01
5.9174166+03	4.2041717+04	1.3532730+04	-4.7091306+01	-9.5361103+00	-6.0089988+01
1.3698578+04	1.3532730+04	5.8421162+04	-1.1456187+01	-1.3899305+01	-4.5714334+01
-3.6210643+00	-4.7091306+01	-1.1456187+01	5.6378766-02	6.7964849-03	5.7145831-02
-7.4684279+00	-9.5361103+00	-1.3899305+01	6.7964849-03	1.7802420-02	3.0934232-02
-2.5763240+01	-6.0089988+01	-4.5714334+01	5.7145831-02	3.0934232-02	2.4607557-01

CSM/LM Covariance at SPS Trim

	1	2	3	4	5	6
1	6.7293315+03	-2.5789777+03	2.4281647+03	3.6227512+00	-1.1662297+00	2.7394027+00
2	-2.5789775+03	2.3366971+04	-3.7577911+03	-2.5315527+01	3.2960069+00	9.8419879+00
3	2.4281647+03	-3.7577911+03	1.8577028+04	5.8848778+00	-2.1581051+00	3.7652694+00
4	3.6227512+00	-2.5315527+01	5.8848778+00	3.0495431-02	-4.4474310-03	-9.7883394-03
5	-1.1662297+00	3.2960070+00	-2.1581051+00	-4.4474310-03	9.8189015-03	1.2852605-03
6	2.7394027+00	9.8419879+00	3.7652694+00	-9.7883394-03	1.2852606-03	5.9334338-02

CSM Covariance at Separation

	1	2	3	4	5	6
1	.71717659+04	-.57646541+04	-.39573151+03	.80874559-00	-.75892542-00	-.33244821+01
2	-.57646541+04	.53849693+05	.16758314+03	-.32829993+02	.51659559+01	.66727899+01
3	-.39573151+03	.16758314+03	.87397744+05	.73748529-01	.13218158+01	.38048398+02
4	.80874559-00	-.32829993+02	.73748529-01	.24133960-01	-.15589334-03	.51965179-03
5	-.75892542-00	.51659559+01	.13218158+01	-.15589334-03	.83329567-02	.44096734-02
6	-.33244821+01	.66727899+01	.38048398+02	.51965179-03	.44096734-02	.37970453-01

LM Covariance at Separation

	7	8	9	10	11	12
7	.71717659+04	-.57646541+04	-.39573151+03	.80874559-00	-.75892542-00	-.33244821+01
8	-.57646541+04	.53849693+05	.16758314+03	-.32829993+02	.51659559+01	.66727899+01
9	-.39573151+03	.16758314+03	.87397744+05	.73748529-01	.13218158+01	.38048398+02
10	.80874559-00	-.32829993+02	.73748529-01	.24133960-01	-.15589334-03	.51965179-03
11	-.75892542-00	.51659559+01	.13218158+01	-.15589334-03	.83329567-02	.44096734-02
12	-.33244821+01	.66727899+01	.38048398+02	.51965179-03	.44096734-02	.37970453-01

CSM/LM Relative Covariance at Staging

	1	2	3	4	5	6
1	.37540329+06	-.29831038+06	.22048842+06	.68685757+03	-.27619992+03	.17490359+03
2	-.29831038+06	.39379489+06	-.36557319+06	-.58964472+03	.34191002+03	-.31729649+03
3	.22048842+06	-.36557319+06	.77918848+06	.44751544+03	-.37260944+03	.58309740+03
4	.68685757+03	-.58964472+03	.44751544+03	.12761613+01	-.53301024-00	.36078307-00
5	-.27619992+03	.34191002+03	-.37260944+03	-.53301024-00	.32307401-00	-.31245753-00
6	.17490359+03	-.31729649+03	.58309740+03	.36078307-00	-.31245753-00	.52675888-00

CSM Covariance at Staging

	7	8	9	10	11	12
7	.67717908+05	-.83862843+05	.10001737+05	.12692996+03	-.54718975+02	.37409280+02
8	-.83862843+05	.12033013+06	-.15608057+05	-.17192908+03	.76603219+02	-.50886457+02
9	.10001737+05	-.15608057+05	.11491009+06	.20897013+02	-.82645006+01	.60952214+02
10	.12692996+03	-.17192908+03	.20897013+02	.25542583-00	-.11428121+00	.70049592-01
11	-.54718975+02	.76603219+02	-.82645006+01	-.11428121+00	.56697836-01	-.27891356-01
12	.37409280+02	-.50886457+02	.60952214+02	.70049592-01	-.27891356-01	.75378537-01

LM Covariance at Staging

	7	8	9	10	11	12
7	.28189594+06	-.19260895+06	.19475570+06	.51668528+03	-.20121001+03	.12119054+03
8	-.19260895+06	.25430693+06	-.32978111+06	-.38650775+03	.25004791+03	-.24736506+03
9	.19475570+06	-.32978111+06	.67066276+06	.39530160+03	-.34749428+03	.52148427+03
10	.51668528+03	-.38650775+03	.39530160+03	.96751986-00	-.39918783-00	.25422979-00
11	-.20121001+03	.25004791+03	-.34749428+03	-.39918783-00	.25941887-00	-.26488177-00
12	.12119054+03	-.24736506+03	.52148427+03	.25422979-00	-.26488177-00	.44607438-00

CSM/ LM Relative Covariance at NCC

	1	2	3	4	5	6
1	.10347794+06	-.30408843+05	.10901304+06	.26847949+03	-.13853095+02	-.43302458+03
2	-.30408843+05	.11276820+05	-.25181140+05	-.82560134+02	.32748027+01	.20244421+03
3	.10901304+06	-.25181140+05	.19863689+06	.28989498+03	-.48336592-00	-.50367573+03
4	.26847949+03	-.82560134+02	.28989498+03	.73702675-00	-.11066135-01	-.14065242+01
5	-.13853095+02	.32748027+01	-.48336592-00	-.11066135-01	.12153242-01	-.13371221-01
6	-.43302458+03	.20244421+03	-.50367573+03	-.14065242+01	-.13371221-01	.48499169+01

CSM Covariance at NCC

	7	8	9	10	11	12
7	.77784586+04	.41836910+04	-.10150875+04	-.71024040+01	-.20749390+01	.13245886+02
8	.41836910+04	.40848044+05	-.66441049+04	-.39396542+02	-.65355071+01	-.32433255-00
9	-.10150875+04	-.66441049+04	.48835016+05	.88001324+01	.50717052+01	.46595283+02
10	-.71024040+01	-.39396542+02	.88001324+01	.41316262-01	.10116072-01	-.13189057-01
11	-.20749390+01	-.65355071+01	.50717052+01	.10116072-01	.10645717-01	-.24047815-01
12	.13245886+02	-.32433255-00	.46595283+02	-.13189057-01	-.24047815-01	.21256365-00

LM Covariance at NCC

	7	8	9	10	11	12
7	.10153377+06	-.19664108+05	.93621469+05	.25044023+03	-.10074462+02	-.43143114+03
8	-.19664108+05	.50982416+05	-.24080192+05	-.10378691+03	-.19866535+01	.19219445+03
9	.93621469+05	-.24080192+05	.18640750+06	.27534002+03	.11520142+02	-.59813785+03
10	.25044023+03	-.10378691+03	.27534002+03	.74480116-00	-.14947143-01	-.14206803+01
11	-.10074462+02	-.19866535+01	.11520142+02	-.14947143-01	.10031172-01	-.25563341-01
12	-.43143114+03	.19219445+03	-.59813785+03	-.14206803+01	-.25563341-01	.48171210+01

CSM/LM Relative Covariance at CSI

	1	2	3	4	5	6
1	.23723853+05	-.15577661+05	-.14515579+05	.40791119+02	-.17399341+02	.10532706+02
2	-.15577661+05	.21210735+05	.48762281+04	-.32755375+02	.12627451+02	-.13836105+02
3	-.14515579+05	.48762281+04	.11292369+06	-.28543089+02	.71398621+01	.94515324+02
4	.40791119+02	-.32755375+02	-.28543089+02	.81025813-01	-.28805362-01	.14786961-01
5	-.17399341+02	.12627451+02	.71398621+01	-.28805362-01	.13406531-01	-.11678607-01
6	.10532706+02	-.13836105+02	.94515324+02	.14786961-01	-.11678607-01	.12593255-00

CSM Covariance at CSI

	7	8	9	10	11	12
7	.52175890+04	-.33396363+04	-.68615418+03	.40449343+01	.46063425-00	.35600623+01
8	-.33396363+04	.11652361+05	.49745964+03	-.11644021+02	.48253166+01	-.37523316+01
9	-.68615418+03	.49745964+03	.82769616+05	-.30529485+01	.47564004-00	.77082042+02
10	.40449343+01	-.11644021+02	-.30529485+01	.15218855-01	-.49762659-02	-.18597462-02
11	.46063425-00	.48253106+01	.47564004-00	-.49762659-02	.81186008-02	.16343589-02
12	.35600623+01	-.37523316+01	.77082042+02	-.18597462-02	.16343589-02	.10846675+00

LM Covariance at CSI

	7	8	9	10	11	12
7	.19749469+05	-.95053644+04	-.97685181+04	.32522968+02	-.12103773+02	.43495889+01
8	-.95053644+04	.10594040+05	.51147805+04	-.20737552+02	.98184492+01	-.16647389+01
9	-.97685181+04	.51147805+04	.33669644+05	-.15178412+02	.23015513+01	.98220598+01
10	.32522968+02	-.20737552+02	-.15178412+02	.66430483-01	-.28406776-01	.96173440-02
11	-.12103773+02	.98184492+01	.23015513+01	-.28406776-01	.19074176-01	-.60208069-02
12	.43495889+01	-.16647389+01	.98220598+01	.96173440-02	-.60208069-02	.25971153-01

CSM/ LM Relative Covariance at CDH

	1	2	3	4	5	6
1	.3598900e+04	.34571680+03	.38025726+04	-.11494448+01	-.36830625+01	.36346614-00
2	.34571680+03	.28649180+05	-.18315955+05	-.24147295+02	-.49012926-00	-.66946018+01
3	.38025726+04	-.18315955+05	.17124392+06	.17881550+02	-.33430663+01	.28436569+02
4	-.11494448+01	-.24147295+02	.17881550+02	.27281217-01	.21412233-02	.47844951-02
5	-.36830625+01	-.49012926-00	-.33430663+01	.21412233-02	.38966530-02	-.33828945-03
6	.36346614-00	-.66946018+01	.28436569+02	.47844951-02	-.33828945-03	.22870824-01

CSM Covariance at CDH

	7	8	9	10	11	12
7	.54871915+04	.25691674+04	-.14603932+04	-.34541417+01	.66289634-00	-.21994319+01
8	.25691674+04	.51171032+05	-.23781294+05	-.50216147+02	-.59985378+01	-.10062969+02
9	-.14603932+04	-.23781294+05	.14431139+06	.23398776+02	-.71611339-00	.18835919+02
10	-.34541417+01	-.50216147+02	.23398776+02	.51521537-01	.61290836-02	.82756158-02
11	.66289634-00	-.59985378+01	-.71611339-00	.61290836-02	.73007426-02	-.21534236-02
12	-.21994319+01	-.10062969+02	.18835919+02	.82756158-02	-.21534236-02	.23305582-01

LM Covariance at CDH

	7	8	9	10	11	12
7	.96022927+04	.12136877+04	-.12079040+04	-.14249548+01	-.32936138+01	.19183929+01
8	.12136877+04	.28876079+05	-.96355778+03	-.28575211+02	-.25003633+01	-.44873067+01
9	-.12079040+04	-.96355778+03	.36870027+05	.27125037+01	.47690663+01	.46804244+01
10	-.14249548+01	-.28575211+02	.27125037+01	.33739567-01	.33010798-02	.40669287-02
11	-.32936138+01	-.25003633+01	.47690663+01	.33010798-02	.11142421-01	-.46260780-02
12	.19183929+01	-.44873067+01	.46804244+01	.40669287-02	-.46260780-02	.21281970-01

CSM/ LM Relative Covariance at TPI

	1	2	3	4	5	6
1	.27220051+05	-.52583933+05	-.74984135+04	.62291576+02	-.24742743+02	.38845972+01
2	-.52583933+05	.15179097+06	.20337919+05	-.16367371+03	.47071895+02	-.10734171+02
3	-.74984135+04	.20337919+05	.94813711+05	-.27934304+02	.70108740+01	-.49064157+02
4	.62291576+02	-.16367371+03	-.27934304+02	.18148395-00	-.56037565-01	.16001764-01
5	-.24742743+02	.47071895+02	.70108740+01	-.56037565-01	.22656730-01	-.31079775-02
6	.38845972+01	-.10734171+02	-.49064157+02	.16001764-01	-.31079775-02	.74508239-01

CSM Covariance at TPI

	7	8	9	10	11	12
7	.83593182+04	-.66747015+04	-.32814657+04	.87234012+01	-.21436573-00	.23173314+01
8	-.66747015+04	.39705127+05	.20348614+05	-.41624527+02	.81186243+01	-.11251723+02
9	-.32814657+04	.20348614+05	.67590063+05	-.26033218+02	.80228337+01	-.48730972+02
10	.87234012+01	-.41624527+02	-.26033218+02	.46425447-01	-.97283034-02	.13625364-01
11	-.21436573-00	.81186243+01	.80228337+01	-.97283034-02	.75039998-02	-.20822653-02
12	.23173314+01	-.11251723+02	-.48730972+02	.13625364-01	-.20822653-02	.01497741-01

LM Covariance at TPI

	7	8	9	10	11	12
7	.28340779+05	-.48048282+05	-.12838587+04	.58533775+02	-.19868039+02	-.17541879-00
8	-.48048282+05	.12307055+06	.81122196+04	-.13549025+03	.46268698+02	.52107762+01
9	-.12838587+04	.81122196+04	.35198275+05	-.81971478+01	.38379017+01	.11639946+01
10	.58533775+02	-.13549025+03	-.81971478+01	.15513645-00	-.55235587-01	-.01585079-02
11	-.19868039+02	.46268698+02	.38379017+01	-.55235587-01	.25755007-01	.48347549-02
12	-.17541879-00	.52107762+01	.11639946+01	-.61585079-02	.48347549-02	.20721862-01

CSM Covariance at Separation Maneuver*

	1	2	3	4	5	6
1	1.1375000+05	-7.1607100+04	9.5268328+03	2.9644140+02	-3.0900410+01	-2.4519910+00
2	-7.1607100+04	1.8072770+06	-2.7429010+04	-1.8484849+03	9.9934299+01	4.6349590+01
3	9.5268328+03	-2.7429010+04	1.1296030+05	3.2822660+01	-3.6567940+00	1.0350490+02
4	2.9644140+02	-1.8484849+03	3.2822660+01	2.4673879+00	-6.0020950-02	-4.8831049-02
5	-3.0900410+01	9.9934299+01	-3.6567940+00	-6.0020950-02	2.2724800-01	-5.4324959-04
6	-2.4519910+00	4.6349590+01	1.0350490+02	-4.8831049-02	-5.4324959-04	2.1956020-01

LM Covariance at Separation Maneuver*

	1	2	3	4	5	6
1	1.1375000+05	-7.1607100+04	9.5268328+03	2.9644140+02	-3.0900410+01	-2.4519910+00
2	-7.1607100+04	1.8072770+06	-2.7429010+04	-1.8484849+03	9.9934299+01	4.6349590+01
3	9.5268328+03	-2.7429010+04	1.1296030+05	3.2822660+01	-3.6567940+00	1.0350490+02
4	2.9644140+02	-1.8484849+03	3.2822660+01	2.4673879+00	-6.0020950-02	-4.8831049-02
5	-3.0900410+01	9.9934299+01	-3.6567940+00	-6.0020950-02	2.2724800-01	-5.4324959-04
6	-2.4519910+00	4.6349590+01	1.0350490+02	-4.8831049-02	-5.4324959-04	2.1956020-01

*Reference 2

Relative CSM, LM Covariance Maneuver*

	1	2	3	4	5	6
1	1.5041070+05	-9.5991110+05	3.1868320+01	9.8683479+02	-1.3362120+01	-3.8709869-02
2	-9.5991110+05	1.0317860+07	3.2811520+01	-1.0773240+04	8.0600300+01	-6.5455289-02
3	3.1868320+01	3.2811520+01	2.7838570+04	-3.4284650-02	4.1442739-02	-8.5407670+00
4	9.8683479+02	-1.0773240+04	-3.4284650-02	1.1294300+01	-7.1449609-02	6.9150279-05
5	-1.3362120+01	8.0600300+01	4.1442739-02	-7.1449609-02	1.1925940-01	-5.5827010-05
6	-3.8709869-02	-6.5455289-02	-8.5407670+00	6.9150279-05	-5.5827010-05	4.2667519-02

CSM Covariance at Concentric Maneuver*

	1	2	3	4	5	6
1	2.5763630+05	-2.9207925+06	1.0226400+04	3.0284180+03	-1.3102859+02	1.0059710+01
2	-2.9207925+06	8.9651710+07	-1.0433890+05	-9.7168590+04	-1.7047450+03	-1.2027620+02
3	1.0226400+04	-1.0433890+05	1.1595490+05	1.1619900+02	-7.3592740+00	-1.0464940+02
4	3.0284180+03	-9.7168590+04	1.1619900+02	1.0555510+02	1.9937540+00	1.3721079-01
5	-1.3102859+02	-1.7047450+03	-7.3592740+00	1.9937540+00	3.0476650-01	-4.3183219-03
6	1.0059710+01	-1.2027620+02	-1.0464940+02	1.3721079-01	-4.3183219-03	2.5594450-01

*Reference 2

LM Covariance at Concentric Maneuver*

	1	2	3	4	5	6
1	1.7564460+05	-2.3033640+06	1.0403690+04	2.4100319+03	-7.7984839+01	1.0482980+01
2	-2.3033640+06	8.1020950+07	-1.0515570+05	-8.8333480+04	-1.8824369+03	-1.2452930+02
3	1.0403690+04	-1.0515570+05	9.0393970+04	1.1725350+02	-7.4711500+00	-9.7052569+01
4	2.4100319+03	-8.8333480+04	1.1725350+02	9.6475749+01	2.1603949+00	1.4211059-01
5	-7.7984839+01	-1.8824369+03	-7.4711500+00	2.1603949+00	2.1802329-01	-4.5716609-03
6	1.0482980+01	-1.2452930+02	-9.7052569+01	1.4211059-01	-4.5716609-03	2.1007050-01

Relative CSM, LM Covariance at TPI*

	1	2	3	4	5	6
1	3.0732250+05	-3.1145750+05	4.9261079+00	4.0678020+02	-2.0560180+02	7.6087259-03
2	-3.1145750+05	3.1270789+06	-6.9936620+01	-3.8147379+03	2.9144959+02	-9.2350219-02
3	4.9261079+00	-6.9936620+01	1.1202570+05	9.3223769-02	-1.3488750-02	-1.6778889+01
4	4.0678020+02	-3.8147379+03	9.3223769-02	4.7138990+00	-3.7317879-01	1.2265369-04
5	-2.0560180+02	2.9144959+02	-1.3488750-02	-3.7317879-01	1.9368879-01	-2.0301029-05
6	7.6087259-03	-9.2350219-02	-1.6778889+01	1.2265369-04	-2.0301029-05	1.8881330-01

*Reference 2

CSM Covariance at TPI*

	1	2	3	4	5	6
1	2.1295489+06	-1.9656650+07	-1.0731070+04	2.1738370+04	-1.7068779+03	1.4630820+01
2	-1.9656650+07	2.3817600+08	1.6703980+05	-2.6198510+05	1.5639960+04	-1.8339439+02
3	-1.0731070+04	1.6703980+05	2.8185190+05	-1.8975120+02	6.8510920+00	7.1717979+01
4	2.1738370+04	-2.6198510+05	-1.8975120+02	2.8836399+02	-1.7318640+01	2.1377820-01
5	-1.7068779+03	1.5639960+04	6.8510920+00	-1.7318640+01	1.4453680+00	-1.1469780-02
6	1.4630820+01	-1.8339439+02	7.1717979+01	2.1377820-01	-1.1469780-02	2.9111080-01

LM Covariance at TPI*

	1	2	3	4	5	6
1	2.1680009+06	-2.2143850+07	-1.1837680+04	2.4623240+04	-1.7644360+03	1.6144460+01
2	-2.2143850+07	2.5381940+08	1.7243260+05	-2.8118730+05	1.7414710+04	-1.9452330+02
3	-1.1837680+04	1.7243260+05	1.7151140+05	-1.9722360+02	7.5379170+00	8.7255459+01
4	2.4623240+04	-2.8118730+05	-1.9722360+02	3.1161740+02	-1.9398499+01	2.2830020-01
5	-1.7644360+03	1.7414710+04	7.5379170+00	-1.9398499+01	1.4624630+00	-1.2457950-02
6	1.6144460+01	-1.9452330+02	8.7255459+01	2.2830020-01	-1.2457950-02	1.0018820-01

*Reference 2

Relative CSM, LM Covariance at MCC 1*

	1	2	3	4	5	6
1	2.0821520+05	1.6529930+05	8.9519379-01	-2.7736279+02	-1.1636110+02	5.9100309-03
2	1.6529930+05	1.4055049+05	6.6666389-01	-2.5876550+02	-1.0146830+02	4.4045299-03
3	8.9519379-01	6.6666389-01	3.9632110+03	-1.4564590-03	-3.6080639-04	1.0962860+01
4	-2.7736279+02	-2.5876550+02	-1.4564590-03	6.0876570-01	2.1454179-01	-9.9666739-06
5	-1.1636110+02	-1.0146830+02	-3.6080639-04	2.1454179-01	8.5929760-02	-2.5799009-06
6	5.9100309-03	4.4045299-03	1.0962860+01	-9.9666739-06	-2.5799009-06	1.0585090-01

CSM Covariance at MCC 1*

	1	2	3	4	5	6
1	8.9365860+05	-1.2239030+07	6.5082409+03	1.3331710+04	-5.0079300+02	1.9843329+01
2	-1.2239030+07	2.9924650+08	-5.2173260+04	-3.2945870+05	4.0739539+03	-3.0205540+02
3	6.5082409+03	-5.2173260+04	1.7896130+05	5.8902759+01	-6.1827720+00	-7.2854879+01
4	1.3331710+04	-3.2945870+05	5.8902759+01	3.6297780+02	-4.3227530+00	3.4339549-01
5	-5.0079300+02	4.0739539+03	-6.1827720+00	-4.3227530+00	4.0483600-01	-1.2174460-02
6	1.9843329+01	-3.0205540+02	-7.2854879+01	3.4339549-01	-1.2174460-02	2.0094990-01

*Reference 2

LM Covariance at MCC 1*

	1	2	3	4	5	6
1	5.2335780+05	-9.8784330+06	5.8258530+03	1.0886730+04	-3.0987889+02	1.6825119+01
2	-9.8784330+06	3.0341060+08	-5.2672900+04	-3.3658050+05	2.5396869+03	-3.0408960+02
3	5.8258530+03	-5.2672900+04	1.7371460+05	6.0104089+01	-5.7857420+00	-8.5518679+01
4	1.0886730+04	-3.3658050+05	6.0104089+01	3.7345050+02	-2.7451029+00	3.4867819-01
5	-3.0987889+02	2.5396869+03	-5.7857420+00	-2.7451029+00	2.9221950-01	-1.0232240-02
6	1.6825119+01	-3.0408960+02	-8.5518679+01	3.4867819-01	-1.0232240-02	9.7190159-02

Relative CSM, LM Covariance at MCC 2*

	1	2	3	4	5	6
1	1.2230720+05	2.9077990+04	9.2253870-01	-9.6230419+01	-5.2741899+01	3.8603780-03
2	2.9077990+04	7.7962700+03	1.8269610-01	-3.5915440+01	-1.4107510+01	7.6068829-04
3	9.2253870-01	1.8269610-01	7.5262920+02	-1.1348680-03	-2.9127420-04	2.2230500+00
4	-9.6230419+01	-3.5915440+01	-1.1348680-03	3.3134250-01	6.3395409-02	-4.8986409-06
5	-5.2741899+01	-1.4107510+01	-2.9127420-04	6.3395409-02	2.6514640-02	-1.2689300-06
6	3.8603780-03	7.6068829-04	2.2230500+00	-4.8986409-06	-1.2689300-06	2.7823540-02

*Reference 2

CSM Covariance at MCC 2*

	1	2	3	4	5	6
1	3.3461060+05	-5.9289449+06	1.1666160+04	6.4887690+03	-1.1031210+02	1.1721150+01
2	-5.9289449+06	3.0833070+08	-1.8171330+05	-3.4519830+05	-3.5369159+03	-2.4386150+02
3	1.1666160+04	-1.8171330+05	8.8630400+04	2.0478170+02	-7.7640710+00	-9.3213739+01
4	6.4887690+03	-3.4519830+05	2.0478170+02	3.8687389+02	4.1141099+00	2.7915809-01
5	-1.1031210+02	-3.5369159+03	-7.7640710+00	4.1141099+00	2.3309840-01	-4.8099469-03
6	1.1721150+01	-2.4386150+02	-9.3213739+01	2.7915809-01	-4.8099469-03	2.4032280-01

CSM Covariance at MCC 2*

	1	2	3	4	5	6
1	1.5950300+05	-3.8246030+06	1.0200100+04	4.2071349+03	-7.6337769+01	9.9287770+00
2	-3.8246030+06	3.0915250+08	-1.8190770+05	-3.4854470+05	-4.4564819+03	-2.4378069+02
3	1.0200100+04	-1.8190770+05	8.7510210+04	2.0666370+02	-7.1870640+00	-9.5708509+01
4	4.2071349+03	-3.4854470+05	2.0666370+02	3.9312190+02	5.1401890+00	2.8121930-01
5	-7.6337769+01	-4.4564819+03	-7.1870640+00	5.1401890+00	2.3391140-01	-4.0415319-03
6	9.9287770+00	-2.4378069+02	-9.5708509+01	2.8121930-01	-4.0415319-03	2.1403249-01

*Reference 2

Relative CSM, LM Covariance at TPF*

	1	2	3	4	5	6
1	1.7213600+05	-1.4271310+05	1.6337230+00	2.7816769+02	-1.1885590+02	1.3005780-03
2	-1.4271310+05	1.1925530+05	-1.4222780+00	-2.2814850+02	9.8134159+01	-1.1742420-03
3	1.6337230+00	-1.4222780+00	1.3004070+04	-1.8118589-04	8.3951879-04	1.1408850+01
4	2.7816769+02	-2.2814850+02	-1.8118589-04	5.3023300-01	-2.3834880-01	-3.3202599-07
5	-1.1885590+02	9.8134159+01	8.3951879-04	-2.3834880-01	1.1028970-01	7.6695789-07
6	1.3005780-03	-1.1742420-03	1.1408850+01	-3.3202599-07	7.6695789-07	1.1239570-02

CSM Covariance at TPF*

	1	2	3	4	5	6
1	1.9892430+05	-1.3813020+06	1.0815790+04	1.7305990+03	-1.1585790+02	9.6020420-01
2	-1.3813020+06	3.0324620+08	-2.9151150+05	-3.5380530+05	-8.3815399+03	-1.4097980+01
3	1.0815790+04	-2.9151150+05	5.5026880+04	3.3461799+02	-3.4813800+00	5.5807259+01
4	1.7305990+03	-3.5380530+05	3.3461799+02	4.1322640+02	9.6569200+00	2.1259300-02
5	-1.1585790+02	-8.3815399+03	-3.4813800+00	9.6569200+00	4.0119850-01	7.7022608-05
6	9.6020420-01	-1.4097980+01	5.5807259+01	2.1259300-02	7.7022608-05	2.8577960-01

*Reference 2

LM Covariance at TPF*

	1	2	3	4	5	6
1	2.4543750+04	-4.5856570+05	1.0051360+04	5.4351439+02	-1.8558230+01	1.0310910+00
2	-4.5856570+05	3.0140770+08	-2.9029720+05	-3.5293790+05	-8.0051349+03	-1.3735310+01
3	1.0051360+04	-2.9029720+05	4.2196630+04	3.3456139+02	-4.0201969+00	4.5310799+01
4	5.4351439+02	-3.5293790+05	3.3456139+02	4.1356499+02	9.3731300+00	2.0975489-02
5	-1.8558230+01	-8.0051349+03	-4.0201969+00	9.3731300+00	2.6838519-01	3.7833510-05
6	1.0310910+00	-1.3735310+01	4.5310799+01	2.0975489-02	3.7833510-05	2.7544799-01

*Reference 2

CSM Covariance at TEI

	1	2	3	4	5	6
1	9.3952696+03	-2.7801765+03	4.6627855+03	4.9309630+00	-2.7053075+00	1.2681555+00
2	-2.7801765+03	3.7037922+04	1.0753822+03	-3.6023173+01	4.3635575+00	1.6368249+00
3	4.6627855+03	1.0753822+03	1.7419428+04	6.3807248-01	-5.3160919+00	-1.6827860+01
4	4.9309630+00	-3.6023173+01	6.3807248-01	3.6732664-02	-6.1072724-03	-9.1478781-04
5	-2.7053075+00	4.3635575+00	-5.3160919+00	-6.1072724-03	9.9420431-03	2.5923271-03
6	1.2681555+00	1.6368249+00	-1.6827860+01	-9.1478781-04	2.5923271-03	6.2185074-02

CSM Covariance at MCC

	1	2	3	4	5	6
1	1.1971730+04	-3.8446076+04	2.7911778+03	3.8022467+01	-5.7517917+00	1.3595430+00
2	-3.8446076+04	5.4090572+05	1.2511103+04	-5.8213659+02	1.0288184+01	-2.0847151+01
3	2.7911778+03	1.2511103+04	2.0841408+04	-1.4155234+01	-4.6845519+00	1.3937746+01
4	3.8022467+01	-5.8213659+02	-1.4155234+01	6.3160262-01	-7.1367791-03	2.7250403-02
5	-5.7517917+00	1.0288184+01	-4.6845519+00	-7.1367791-03	1.5664116-02	-2.8558834-04
6	1.3595430+00	-2.0847151+01	1.3937746+01	2.7250403-02	-2.8558834-04	1.6485119-01

CSM Covariance at SPS Deorbit

	1	2	3	4	5	6
1	9.5799427+03	-1.3460569+04	-3.7676447+03	1.4553343+01	-2.4583021+00	-8.1597683-01
2	-1.3460569+04	2.0769431+05	1.9996610+04	-1.8500058+02	5.8831874+00	4.8342593+01
3	-3.7676447+03	1.9996610+04	1.0675306+05	-1.6267799+01	2.7974383+00	-3.6146518+01
4	1.4553343+01	-1.8500058+02	-1.6267799+01	1.7321418-01	-7.7297401-03	-3.9207193-02
5	-2.4583021+00	5.8831874+00	2.7974383+00	-7.7297401-03	9.6369972-03	1.6822272-03
6	-8.1597683-01	4.8342593+01	-3.6146518+01	-3.9207193-02	1.6822272-03	5.0764533-02

CSM Covariance at Reentry

	1	2	3	4	5	6
1	2.7534731+04	-8.8091307+03	-3.1111911+04	3.1904402+01	5.4736063+00	-1.0345973+02
2	-8.8091307+03	7.9415505+03	1.6344575+04	-1.6034954+01	-2.8034395+00	5.6469690+01
3	-3.1111911+04	1.6344575+04	1.1094395+05	-3.7826029+01	-2.1409097+01	3.2220918+02
4	3.1904402+01	-1.6034954+01	-3.7826029+01	5.9208491-02	3.5899072-03	-1.3545477-01
5	5.4736063+00	-2.8034395+00	-2.1409097+01	3.5899072-03	6.2615114-03	-5.7884980-02
6	-1.0345973+02	5.6469690+01	3.2220918+02	-1.3545477-01	-5.7884980-02	1.1060508+00

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